Budget Setting Strategies for the Company's Divisions

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Abstract

The paper deals with the issue of budget setting to the divisions of a company. The approach is quantitative in nature both in the formulation of the requirements for the set-budgets, as related to different general managerial objectives of interest, and in the modelling of the inherent uncertainties in the divisions' revenues. Solutions are provided for specific cases and conclusions are drawn on different aspects of this issue based on analytical and numerical analysis of the results. From a more general standpoint the paper is also intended to set the ground for a schematic and precise approach to the managerial problem of budget-setting.

Keywords: budgeting, uncertainty, achievability, responsiveness, fairness.

JEL-codes: C44, M40.

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1 Introduction

We study the issue of setting budgets to the divisions of a company by its top manager. In this paper we consider budget setting for revenue budgets, but the models and results can easily be adapted to cost budgets. Budget setting is an important policy device with various managerial aspects. Primarily it entails the determination of the total company budget, which is by definition the sum of the divisional budgets. The top manager wants this total budget to be realistic in terms of achievability (i.e., the probability that the revenues of the company as a whole will be at least the set budget). Then there are managerial and organizational objectives that the budget setting serves or can promote. In this paper we shall focus on two types of objectives: one relates to the achievability of the set budget in the divisions, the second - to the responsiveness of the set budget to those proposed by the divisions' managers, measured by the ratio of the set budget to the proposed one. Then there is the overall objective of "fairness", i.e., treating the managers equally in terms of the above two objectives.

Given these objectives and the above mentioned primary goal of achievability of the total budget for the company as a whole, the top manager can formulate decision problems whose solutions are the required set budgets. There are different possibilities here and thus the first stage of the analysis is creating a scheme of problem-formulation variations of interest. Solving such problems for a variety of modelling situations is the next stage. Then, the results obtained for the divisional budgets are used to demonstrate, analytically or by numerical analysis, some fundamental aspects of the budgeting solutions.

We begin in Section 2 by presenting the underlying mathematical model and introducing some necessary notation. Section 3 presents analytical solutions to budgeting problems where the aim is to satisfy fairness in regard to achievability and responsiveness, respectively. The results are illustrated in a numerical example. Section 4 shows how the two fairness objectives can be combined. Section 5 concludes.

2 Problem formulation

We consider a company with n divisions that are supervised by subordinate managers who each have to report to a single superior. The general aim is to set a target budget v_i for the revenue of division i, $i = 1, \ldots, n$. The main inputs used in this regard are the probabilistic information on the random variables of the revenues Y_i, $i = 1, \ldots, n$, of the divisions, and the proposed budgets d_i by the divisions' managers. We denote by $F_i(.)$ the cumulative distribution function (cdf) of Y_i, $i = 1, \ldots, n$. For simplicity of exposition we assume here that the $F_i(.)$ are continuous. The $F_i(.)$, $i = 1, \ldots, n$, contain all the probabilistic information on $Y_1, \ldots, Y_n$ when they are assumed independent and otherwise the multivariate distribution of $\underline{Y} = (Y_1, \ldots, Y_n)$ is needed. The revenue of the company as a whole is given by

$$Y_{\text{tot}} = \sum_{i=1}^{n} Y_i.$$

The distribution of Y_{tot} is completely determined by the marginal distributions $F_i(.)$, or alternatively the multivariate distribution of $\underline{Y}$ when revenues are dependent. Throughout we use the suffix *tot* to denote summation over all divisions of the company. Thus, in particular,

$$v_{\text{tot}} = \sum_{i=1}^{n} v_i. \tag{1}$$

In the idealistic situation in which the top manager can fully rely on his subordinates' proposals, the trivial solution to the budget setting problem seems to be to set $v_i = d_i$, and consequently, $v_{\text{tot}} = \sum_{i=1}^{n} d_i$. However, this approach has two major drawbacks:

i) Otley and Berry (1979) observed that proposed budgets d_i that correspond to challenging probabilities of achievement for the divisions can lead to a virtually impossible to reach budget for the company as a whole. Mathematically, when $\Pr(Y_i \geq d_i) = \beta_i$, $i = 1, 2, \ldots, n$ with $\beta_i < 0.5$, then typically one has that $\Pr(Y_{\text{tot}} \geq \sum_{j=1}^{n} d_j) = \alpha \ll \max_{1 \leq i \leq n} \beta_i$.

ii) A well-known phenomenon is the incentive of managers to create *budgetary slack*. They may for example want to obtain a budget that is easy to achieve, especially when this budget is used for evaluation purposes. Consequently, the d_i may not represent reasonable estimates.

Thus, setting target budgets as proposed by the subordinates and then using their aggregate as the company target budget is not the right thing to do. However, participation in the process of budget setting can make the subordinate manager more committed to it and can thus improve performance. Therefore, large deviations from the proposed d_i may not be desirable.

Given the above, the top manager should set the v_i in such a way that two objectives are met. The primary objective concerns the total budget v_{tot}. The goal here is the achievability of the total budget v_{tot} or, more precisely, that $\Pr(Y_{\text{tot}} \geq v_{\text{tot}}) \geq \alpha$, for a prespecified α $(0 \leq \alpha \leq 1)$. Then, since targets are also used for the evaluation of the subordinate's performance, the division of v_{tot} into $v_i,\ i = 1, \ldots, n$, should be "fair" in terms of two objectives: the probabilities of achievement for the subordinate managers, and the degree in which the target v_i deviates from the proposed d_i, should not differ too much among subordinates.

Several potential solutions are considered here and they all follow the same pattern: first find the maximal level of v_{tot} that yields an acceptable probability of achievement, i.e. $P(Y_{\text{tot}} \geq v_{\text{tot}}) = \alpha$, for a predetermined α, i.e.

$$v_{\text{tot}} = F_{Y_{\text{tot}}}^{-1}(1 - \alpha), \tag{2}$$

where $F_{Y_{\text{tot}}}(.)$ denotes the cdf of Y_{tot}, and then allocate v_{tot} to the divisions so as to satisfy other managerial objectives as stated above.

3 Budget solutions for the achievability and responsiveness objectives

We first obtain solutions for each of the fairness objectives separately with the requirement being complete fairness with regard to the objective concerned. However, an optimal solution with respect to one objective may not perform well with respect to the other one. This may require some balancing between the objectives and this issue is considered in Section 4.

3.1 Solution for the achievability objective

The probability of achievement of the budget v_i set to division i, $i = 1, \ldots, n$, is given by

$$\beta_i = \Pr(Y_i \geq v_i), \quad i = 1, \ldots, n, \tag{3}$$

and complete fairness in that regard among divisions exists if

$$\beta_i = \beta, \quad \text{for all } i = 1, \ldots, n, \tag{4}$$

for some $\beta \in [0, 1]$, i.e. all the divisions have the same probability of achievement for their respective budgets.

Then, following our pattern, the problem that needs to be solved is: given a prespecified probability of achievement α for the overall budget, find $(v_1, \ldots, v_n)$ with $\sum_{j=1}^{n} v_j = v_{\text{tot}}$, and β such that

$$\begin{aligned} &\Pr(Y_{\text{tot}} \geq v_{\text{tot}}) = \alpha, \\ \text{and} \quad &\Pr(Y_i \geq v_i) = \beta, \quad \text{for all } i = 1, \ldots, n. \end{aligned} \tag{5}$$

Since the $F_i(.)$ are continuous, there is a unique solution for (5), but in general there is no useful explicit representation for it. However, for the collections of distributions that possess the location-scale property such a general explicit solution is possible. This location-scale property is defined by the existence, for all i, of constants a_i and $b_i > 0$, such that

$$F_i(x) = G\left(\frac{x - a_i}{b_i}\right), \quad i = 1, \ldots, n,$$

for some cdf $G(.)$ that does not depend on (a_i, b_i). Well-known families of distributions that posses this property are the normal, uniform, exponential and if the shape parameter is kept fixed also the the gamma and Weibull distribution.

Then, since $G(.)$ and $F_i(.)$ are continuous, (4) can be rewritten as

$$F_i(v_i) = F_j(v_j) \;\Leftrightarrow\; G\left(\frac{v_i - a_i}{b_i}\right) = G\left(\frac{v_j - a_j}{b_j}\right) \;\Leftrightarrow\; \frac{v_i - a_i}{b_i} = \frac{v_j - a_j}{b_j}.$$

Combined with (1) this yields the target budgets

$$v_i = a_i + b_i \frac{v_{\text{tot}} - a_{\text{tot}}}{b_{\text{tot}}}, \quad i = 1, \ldots, n, \tag{6}$$

and the probability of achievement for the divisions

$$\beta = 1 - G\left(\frac{v_{\text{tot}} - a_{\text{tot}}}{b_{\text{tot}}}\right), \quad i = 1, \ldots, n. \tag{7}$$

We now illustrate the above procedure for the normal family of distributions, i.e. we consider the case where

$$\underline{Y} = (Y_1, \ldots, Y_n) \sim \; \mathrm{N}\,(\underline{\mu}, \Sigma), \tag{8}$$

where $\underline{\mu} = (\mu_1, \ldots, \mu_n)$ is the (marginal) means vector and $\Sigma = [\sigma_{ij}]_{\substack{i=1,\ldots,n\\ j=1,\ldots,n}}$ the covariance matrix with σ_{ij} denoting the covariance of Y_i and Y_j $(i, j = 1, \ldots, n)$. Note that this includes as a special case the situation with independence between divisions' revenues, which corresponds to Σ being diagonal.

It then follows that

$$\begin{aligned} Y_i &\sim \mathrm{N}(\mu_i, \sigma_i^2), \qquad i = 1, \ldots, n, \\ Y_{\text{tot}} &\sim \; \mathrm{N}\,(\mu_{\text{tot}}, \sigma^2), \end{aligned}$$

where $\sigma_i := \sqrt{\sigma_{ii}}$, and $\sigma := \sqrt{\underline{e}'\Sigma\underline{e}}$, with $\underline{e} := (1, \ldots, 1)$.

For a given α it then follows from (2) that

$$v_{\text{tot}} = \mu_{\text{tot}} + z_\alpha \sigma, \tag{9}$$

where z_α is the $(1 - \alpha)^{\text{th}}$ quantile of the standard normal distribution. Next, we use the fact that the normal distribution has a location-scale parameter, with $G(.)$ in this case being the standard normal distribution function and $a_i = \mu_i$, $b_i = \sigma_i$, $i = 1, \ldots, n$. When these parameters are substituted into (6) we obtain

$$v_i = \mu_i + \frac{\sigma_i}{\sigma_{\text{tot}}} z_\alpha \sigma, \quad i = 1, \ldots, n, \tag{10}$$

and the resulting probability of achievement in each division, from (7), is

$$\beta = 1 - G\left(\frac{\sigma}{\sigma_{\text{tot}}} z_\alpha\right). \tag{11}$$

Notice that (11), when inverted, provides a general formula for effects observed by Otley and Berry (1979):

- Consider the case with independent revenues. Then targets v_i that correspond to reasonable values of β can lead to a very small α, i.e. a virtually impossible target v_{tot} for the company as a whole. Indeed, the inverse of (11) reads

  $$\alpha = 1 - G\left(\frac{\sigma_{\text{tot}}}{\sigma} z_\beta\right). \tag{12}$$

  So when $\beta < 0.5$ (and hence $z_\beta > 0$), then $\alpha < \beta$, since $\sigma_{\text{tot}} = \sum_{i=1}^n \sigma_i > \sigma = \sqrt{\sum_{i=1}^n \sigma_i^2}$. If the ratio between σ_{tot} and σ is relatively large, then the difference between α and β will be large. For instance, if all the σ_i are equal, then $\sigma_{\text{tot}}/\sigma$ increases as $\sqrt{n}$, and can thus be large even for moderate values of n.

α	0.05	0.30	0.50	0.75	0.95
β	0.28	0.43	0.50	0.59	0.72

  (13)

  The table in (13) shows an example of the relationship between α and β for the case of $n = 8$, with each division having normally distributed revenue with $\sigma_i = 4$. Notice that a reasonably optimistic probability of achievement of 0.28 for the divisions leads to a very low probability of achievement of 0.05 for the company as a whole.

- Positive correlation between the divisions' revenues makes the difference between α and β smaller. Indeed (9) immediately implies that when $\sqrt{\underline{e}'\Sigma\underline{e}} > \sqrt{\sum_{i=1}^n \sigma_i^2}$, and $\alpha < 0.5$, then the resulting v_{tot} will be higher, and consequently β will be lower, than in the independence case. The opposite holds when $\alpha > 0.5$. Consequently, the difference between α and β will be smaller than in the independence case when there is positive correlation between divisions' revenues.

Equivalently, (11) implies that when $\alpha < 0.5$, the solution to (5) yields $\beta > \alpha$. It can be argued that high β can create laxness in the attitudes of the divisions' managers. Another objective, therefore, could be minimization of the probability of achievement of the manager that has the easiest budget (and thereby setting the lowest possible upper bound for the probabilities of achievement to all managers). This translates to the optimization problem

$$\begin{aligned} &\min_{(v_1,\dots,v_n)} \max_{1\leq i\leq n} \Pr(Y_i \geq v_i) \\ &\text{s.t. } P(Y_{\text{tot}} \geq v_{\text{tot}}) = \alpha. \end{aligned} \tag{14}$$

It is obvious however that the optimal solution to this problem satisfies (4). Indeed, imagine for example that in an optimal solution $(v_1, \dots, v_n)$ of (14) one has $\beta_k = \max_{1\leq i\leq n} \beta_i > \beta_j$, for some j. Then, by reallocating part of v_j to v_k, while keeping v_{tot} fixed, one can decrease β_k and still have that $\beta_k \geq \beta_j$, which contradicts the optimality of $(v_1, \dots, v_n)$. Thus, any solution to (14) satisfies (4), and is therefore equal to the unique solution of problem (5).

3.2 Solution for the responsiveness objective

Another important aspect the top manager has to take into account is the effect of *budgetary participation*. Positive effects of budgetary participation on performance are known from the literature.[1] In our model budgetary participation is incorporated through the proposed budgets d_i, $i = 1, \dots, n$, by the managers. The "closeness" between the set budget v_i and the proposed budget d_i can then be seen as the degree to which the division's manager effectively participated in the budgetary process. In view of that the top manager wants a set budget v_i to be as close as possible to the proposed budget d_i, $i = 1, \dots, n$. As a measure to the "closeness" of v_i to d_i we choose the ratio $k_i = v_i/d_i$.

As we did with the achievability objective it is assumed that the manager, when using this objective, wants the ratios k_i to be equal for all managers. This yields

[1] After seminal works of e.g. Buckley and McKenna (1972) and Brownell (1982), an extensive literature has been developed on this issue. See e.g. Magner et al. (1995).

the following problem: find budgets $(v_1, \dots, v_n)$, and a ratio k, satisfying

$$\begin{aligned} & P(Y_{\mathrm{tot}} \geq v_{\mathrm{tot}}) = \alpha, \\ \text{and} \quad & v_i = k d_i, \quad i = 1, \dots, n. \end{aligned} \tag{15}$$

With v_{tot} determined by (2), this immediately yields the solution

$$v_i = \frac{v_{\mathrm{tot}}}{d_{\mathrm{tot}}} d_i, \quad i = 1, \dots, n. \tag{16}$$

Now consider the case where $v_{\mathrm{tot}} > d_{\mathrm{tot}}$. Then the top manager knows that at least one manager has to receive a revised budget that is higher than his proposed budget. Therefore, another objective may be to minimize $k_i = v_i/d_i$ for the manager who gets the budget that yields the highest k_i (and thereby setting the lowest possible upper bound for this ratio for all managers). This translates to the optimization problem

$$\begin{aligned} & \min_{(v_1,\dots,v_n)} \max_{1 \leq i \leq n} k_i \\ & \text{s.t. } P(Y_{\mathrm{tot}} \geq v_{\mathrm{tot}}) = \alpha. \end{aligned} \tag{17}$$

As we saw earlier with the previous objective, it is again apparent that problems (15) and (17) have the same solution. When $v_{\mathrm{tot}} < d_{\mathrm{tot}}$, problem (17) can be altered to a max-min problem that also results in the same solution as in (16).

3.3 A numerical example

We now demonstrate the budget setting approaches above by a numerical example. Consider a company with eight divisions. Their distributions are normal distributions $N(10, \sigma_i)$ with

$$\begin{aligned} & \sigma_i = 2, \quad i = 1, \dots, 4, \\ & \sigma_i = 4, \quad i = 5, \dots, 8. \end{aligned} \tag{18}$$

The subordinates propose the following target budgets:

$$\begin{aligned} & d_1 = 8, \quad d_2 = 9, \quad d_3 = 10, \quad d_4 = 11, \\ & d_5 = 8, \quad d_6 = 9, \quad d_7 = 10, \quad d_8 = 11. \end{aligned} \tag{19}$$

Notice that although managers $i = 1, 2, 3$, and 4 have the same revenue distribution, they propose different targets. Whereas manager 1 is relatively pessimistic ($P(Y_1 \geq d_1) > 0.5$), manager 4 is more optimistic ($P(Y_4 \geq d_4) < 0.5$).

Now assume that the top manager wants to set a total budget v_{tot} that is achievable with probability $\alpha = 0.3$.

First we consider a situation with independent budgets. The distribution of the total revenues Y_{tot} is then given by $\text{N}(\mu_{\text{tot}}, \sigma^2)$, with $\mu_{\text{tot}} = 80$, and $\sigma^2 = 80$. The optimal set budgets for the achievability and responsiveness objective can be easily calculated using formulas (10) and (16), respectively. In Table 1(a) one finds the

v_i	β_i	k_i
10.39	0.4225	1.2989
10.39	0.4225	1.1545
10.39	0.4225	1.0391
10.39	0.4225	0.9446
10.78	0.4225	1.3477
10.78	0.4225	1.1980
10.78	0.4225	1.0782
10.78	0.4225	0.9802
84.69	0.0000	0.4031

(a)

v_i	β_i	k_i
8.91	0.7063	1.1143
10.03	0.4942	1.1143
11.14	0.2838	1.1143
12.26	0.1295	1.1143
8.91	0.6069	1.1143
10.03	0.4971	1.1143
11.14	0.3875	1.1143
12.26	0.2862	1.1143
84.69	0.5768	0.0000

(b)

Table 1: The achievability (a) and responsiveness (b) objective

unique solution where the d_i are revised in such a way that the existing differences in probabilities of achievement vanish. If he wants to revise the d_i with equal proportions for all agents, the solution is found in Table 1(b). The last rows in Tables 1(a) and (b), present v_{tot}, $\max_{i,j}\{\beta_i - \beta_j\}$, and $\max_{i,j}\{k_i - k_j\}$.

Let us now consider a situation with dependence. The marginal distributions of the Y_i are the same as before, but $\underline{Y}$ is now given by (8) with correlation coefficients

$\rho_{ij} = \sigma_{ij}/(\sigma_i \sigma_j) = 0.9$, for all $i \neq j$. Tables 2(a) and (b), present solutions for the achievability and responsiveness objectives, respectively.

v_i	β_i	k_i
11.00	0.3081	1.3753
11.00	0.3081	1.2225
11.00	0.3081	1.1003
11.00	0.3081	1.0002
12.01	0.3081	1.5007
12.01	0.3081	1.3339
12.01	0.3081	1.2005
12.01	0.3081	1.0914
92.03	0.0000	0.5004

(a)

v_i	β_i	k_i
9.69	0.5621	1.2109
10.90	0.3266	1.2109
12.11	0.1458	1.2109
13.32	0.0484	1.2109
9.69	0.5311	1.2109
10.90	0.4111	1.2109
12.11	0.2990	1.2109
13.32	0.2032	1.2109
92.03	0.5136	0.0000

(b)

Table 2: The achievability (a) and responsiveness (b) objective with dependence

Comparing with Tables 1(a) and (b), we observe that

i) The positive correlations between the divisions' revenues result in a higher variance of Y_{tot} ($V(Y_{\text{tot}}) = \underline{e}'\Sigma\underline{e} = 526.4$, compared to $V(Y_{\text{tot}}) = 80$ in the independence case). Consequently, the required total budget in the dependence case ($v_{\text{tot}} = 92.03$) is significantly higher than the required total budget in the independence case ($v_{\text{tot}} = 84.69$).

ii) For the achievability objective, the probability of achievement β for the divisions has decreased since the total budget v_{tot} to be allocated among the divisions has increased. In particular, the difference between α and β reduces from 0.1225 (see Table 1(a)) to 0.0081 (see Table 2(a)) as a consequence of the positive correlation between the divisions.

iii) For the responsiveness objective, the k has increased, and hence positive correlation has a negative effect on the performance of this criterion.

So, both in the cases of independence and dependence, it is possible to find targets that achieve perfect fairness with regard to either one of the objectives. Notice however that, for the achievability objective in the independence case for example, the top manager has to increase the proposed budget of manager 5 by 34.77%, whereas he has to decrease the proposed budget of manager 4 by 5.54%, in order to do away with differences in probability of achievement. More generally, we observe that the solution for the complete fairness with regard to the achievability objective does not perform well for the responsiveness objective and on the other hand the solution for complete fairness with regard to the responsiveness objective does not perform well for the achievability objective. We therefore consider combined objectives.

4 Combined objectives

Since a division according to (15) completely relies on the targets d_i proposed by the subordinates, and does not take into account potential different attitudes with respect to budgetary slack, such a division may be very unfair with respect to the achievement objective. On the other hand, if budgets are set so as to achieve equal probabilities of achievement (problem (5)), then it is unlikely that the resulting solution also achieves fairness with respect to responsiveness (as in (15)), because the latter depends on the d_i whereas the former does not.

In view of the above, some control of the other objective can be achieved by constrained optimization as in the following two problems

$$\begin{aligned} &\min_{(v_1,\dots,v_n)} \max_{i,j} \{\beta_i - \beta_j\} \\ &\text{s.t. } \max_{i,j} \{k_i - k_j\} \le \rho_1, \text{ and (2)} \end{aligned} \tag{20}$$

or

$$\begin{aligned} &\min_{(v_1,\dots,v_n)} \max_{i,j} \{k_i - k_j\} \\ &\text{s.t. } \max_{i,j} \{\beta_i - \beta_j\} \le \rho_2, \text{ and (2).} \end{aligned} \tag{21}$$

In these problems instead of perfect fairness with respect to one objective the best possible result is achieved while keeping a lid, as represented by the preset constants ρ_1 and ρ_2, on the other objective. To illustrate the above, we return to the example in Section 3.3 with independence between divisions' revenues.

To find a better balance between the two objectives we turn to the optimization problems (20) or (21). First, consider the problem defined by (20), with the limit on the difference between the k_i set at $\rho_1 = 0.3$. Numerical optimization of this model yields the results shown in Table 3(a). Similarly, solving optimization problem (21),

v_i	β_i	k_i
10.05	0.4906	1.2559
10.51	0.3984	1.1683
10.48	0.4061	1.0475
10.52	0.3984	0.9559
10.05	0.4953	1.2559
11.03	0.3984	1.2256
11.03	0.3984	1.1030
11.03	0.3984	1.0027
84.69	0.0969	0.3000

(a)

v_i	β_i	k_i
9.64	0.5720	1.2047
10.65	0.3720	1.1837
10.65	0.3720	1.0653
10.65	0.3720	0.9685
9.64	0.5361	1.2047
10.84	0.4166	1.2047
11.31	0.3720	1.1307
11.31	0.3720	1.0279
84.69	0.2000	0.2362

(b)

Table 3: Combined objectives

with the limit on the differences between the β_i at $\rho_2 = 0.2$, yields the results shown in Table 3(b).

We see, for instance, that where the maximal difference between the β_i when the k_i are equal, is 0.5768 (see Table 1(b)) it can be decreased to 0.20, with the "price" for that being some variability in the k_i, more precisely, a maximal difference of 0.2362 between them (see Table 3(b)). In general, the manager can make the desired tradeoff between the two objectives by choosing one of the two problems, (20) or (21), with a corresponding value for ρ_i.

5 Conclusions

The paper provides a formal consideration of the issue of budget setting to divisions. A key aspect of the modelling is the incorporation of the inherent uncertainties in future revenues.

The focus is on the two managerial objectives, as viewed from the top management, of budget achievability and budgetary participation. Balancing is required to ensure that managers are treated fairly and in a considerate manner with respect to both objectives while the top manager's constraints on the total budget achievability is controlled. This can be achieved by formulating optimization problems which transform the above requirements into exact quantitative terms. Such problems can then be solved for different modelling settings yielding desirable budget setting solutions.

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